A STUDY OF DISTRIBUTION OF POST - POLIO RESIDUAL PARALYSIS IN BUNDELKHAND REGION

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1989. VIRENDRA KUMAR DUBEY

DEDICATED TO

MY PARENTS

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C E R T I F I C A T E

This is to certify that the work entitled "A STUDY OF DISTRIBUTION OF POST-POLIO RESIDUAL PARALYSIS IN BUNDELKHAND REGION" was carried out by DR. VIRENDRA KUMAR DUBEY himself, under my constant supervision and guidance. The observations and results recorded were checked and varified by me periodically.

This thesis fulfils the basic ordinances governing the submission of thesis for M.S. (Orthopaedics) laid down by Bundelkhand University.

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C E R T I F I C A T E

This is to certify that DR. VIRENDRA KUMAR DUBEY has worked on "A STUDY OFDISTRIBUTION OF POST-POLIO RESIDUAL PARALYSIS IN BUNDELKHAND REGION", under my guidance and supervision. His observations and results were checked by me from time to time.

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I feel emotionally involved with the patients of poliomyelitis. May the almighty bless my future career so that I may be able to allay the suffering of such patients.

Virendra Kumar Dubey

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C O N T E N T S

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INTRODUCTION

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Death before maturity is the usual fate of the untreated crawling crippled child in developing countries. Most children with poliomyelitis, however, when upright, and walking with supports or following operations are accepted by the community, educated by parents and relatives and employable when they reach maturity.

Poliomyelitis is a generalized infection which may involve the whole body, including the muscles directly and liver, spleen and gut in acute stage. The central nervous system manifestations, however, with the involvement of brainstem and anterior horn cells of the spinal cord are the only permanent manifestations of the systemic disease. The residual effects of poliomyelitis are due to destruction of the anterior horn cells of the spinal cord and the brain stem. This causes a lower motor neurone type of asymetrical flaccid paralysis with normal sensations. The muscles affected depend upon level of the spinal cord involved, but the paralysis tends to affect certain muscle groups more often than others and the lower limbs are more often involved than the upper ones.

At the end of an year of treatment, the permanent paralysis and disability is known. Except in a very few severely affected patients no further benefit is likely to arise from continuation of physiotherapy, muscle power remaining unchanged.

Once permanent paralysis is established, no further improvement can be expected by natural means. Treatment is directed towards prevention and if necessary, correction of deformity and use of reconstructive surgical procedures that may enhance residual function.

The severity of paralysis following an attack of acute anterior poliomyelitis shows extreme variation. At one end of the scale, the patients may show paralysis of only one or two muscles which may recover completely, at the other end there may be paralysis of almost all four limbs and trunk. The distribution of paralysis shows at first sight no logical distribution. It is not related to nerve root or peripheral nerve distribution and the loss of power in any muscle may be of any degree from slight paresis to complete paralysis.

It is the object of this study to review this distribution of paresis and paralysis in the muscles of lower limb, trunk and upper limb, to account for its disposition in terms of the destruction of motor nerve cells in the spinal cord, and to indicate the practical application of the findings in the management of poliomyelitis.

The distribution of muscle weakness is a matter of considerable importance from the point of view of joint mechanics. When there is a marked imbalance of muscle power in one of a pair of muscles having antagonistic

action, the weak one may show, instead of improvement, a progressive loss of power over a period of years. For example, without special treatment a weak muscle such as the tibialis anterior may gradually deteriorate, become unduly lengthened, and allow the opposing gastrocnemius to become shortened.

In these instances, we have a situation, which may lead to progressive deformity unless, appropriate therapeutic measures are taken. There may also be progressive loss of muscle function by prolonged immobilization and through overstretching. In the late stages of the disease, even as long as 20 years after the onset, it is possible to increase muscle strength by progressive resistance exercises. Although the percentage increase of muscle strength may not be great by these methods, the improvement in function is often gratifying, enabling the patients to do away with braces or other supports, and to carry on various activities with much less fatigue.

Another phenomenon which has been included in present study is of associated paralyses. Some muscles or muscle groups have a tendency to be affected or spared together. These observations have been applied to the prognosis in individual patients and have been found to be valuable in making decisions about the management of paralysis. A patient with paralysis of the quadriceps,

hip adductors and hip flexors may be prescribed a caliper at an early date during the convelascent stage. These muscles have tendency to be involved together. Usually when both associated muscles are paralysed the prognosis for quadriceps recovery is very bad. Therefore one can safely predict that the quadriceps is not going to recover and thereby render the expensive caliper useless. On the other hand when both associated muscles are paretic or normal, there is an excellent prognosis for all muscles including quadriceps.

The irregular or patchy involvement of muscles with intact sensations is the characteristic of poliomyelitis which distinguishes it from other neurological disorders. This pattern offers great advantage to the treating surgeon for he may select an appropriate muscle for the redistribution of muscle power in the otherwise normal limb. The knowledge of the frequency of involvement of various muscles may be of great help in these redistribution of muscle power procedures. Keeping this in mind a study has been proposed to find out the involvement of various muscles and to identify any pattern if possible.

AIMS OF STUDY

1. To review the distribution of paresis and paralysis in the muscles of the body.

2. To indicate the practical application of the findings in the management of poliomyelitis.
3. In clinical practice a study of the distribution of muscle paresis and paralysis may be of help in the diagnosis particularly of poliomyelitis without any history of fever and in the prognosis and management of these cases.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

HISTORICAL ASPECT

Poliomyelitis is said to have occured nearly 6000 years ago in the time of ancient Egyptians, the evidence for this, which is not yet fully proved, is in the withered and deformed limbs of certain Egyptian mummies (3700 B.C.). In 1580 - 1350 B.C. the priest Ruma was shown on a plaque with a withered leg and equinus foot which was probably poliomyelitis.

In 1559 a painting by Pieter Bruegel, showed a crippled beggar which might not necessarily be polio, though it probably did occur during this period in England. In 1789, there is first known description of poliomyelitis by Underwood.

Poliomyelitis was recognized as clinical entity in the first half of the 19th century. Outbreaks were reported by Badham in England in 1834 and by Calmer in USA in 1843. Von Heine published his monograph describing the clinical aspects of the disease in Germany in 1840. First epidemic of poliomyelitis occured in 1834 in the Island of St. Helena. Larger epidemics appeared at the end of the 19th century in Scandinavia and subsequently in North America, Australia and Newzealand. Sporadic outbreaks continued in Great Britain, with the first major epidemic in 1947. In the Scandinavian countries and in the United States large scale epidemics have occured, but with the

immunization programmes using both the salk and sabin vaccines, no large scale epidemic has occured recently. The pathological process in poliomyelitis with the involvement of the anterior horn cells of the spinal cord was first described by Duchenne in 1855.

INITIAL PARALYSIS

The most important and the most interesting feature of the disease is the muscle paralysis and its sequelae. In fact, the discovery of weakness or paralysis in one or more muscles may be the first certain sign that a patient is suffering from acute anterior poliomyelitis at all. The paralysis usually reaches its maximum severity within 48 hours though it may in some cases containue to increase or involve other limbs over the course of several days. Occasionally a second wave of paralysis may follow a week or more after the complete subsidence of the initial bout of paralysis, especially if the patient has been allowed to become ambulant too soon.

At the end of paralytic stage, a patient may have any combination of paralysis from weakness of one or two muscles in a limb, to complete quadriplegia. Fortunately for those who areextensively affected, the level of paralysis at this time is not directly related to the degree of recovery that may ultimately occur. For example, one limb, all of whose muscles are paralysed at the height of the acute illness may show a return of

activity in almost every muscle after 2 or 3 weeks, while the equally affected opposite limb may remain completely and permanently paralysed.

MUSCLE RECOVERY

End of the fourth week is a convenient time at which to make a detailed assessment of the residual paralyses and parases relevant to the future state of limbs. At this stage patient has recovered from the effects of acute illness as such and much or all of pain and tenderness in muscles has subsided. This work was done by Sharrard (1957). He studied the recovery of muscles in upper and lower limbs. It was rapid between the end of the first month and the end of the second.

After this the recovery rate steadily diminished until at the twelfth month, for practical purposes recovery ceased. A small further increase in power can result in selected muscles if they are given intensive muscle training upto the end of the second year, but it is doubtful, except in particular instances, whether this small amount of extra power is worth obtaining because it often disappears again when the training routine ceases. At the end of two years no further recovery in any individual muscle ever occured provided that the patient had been treated properly and that no deformity had arisen.

Sharrard (1957) further made it clear that these results apply to the recovery of muscles and not to

functional recovery in a limb or in a patient as a whole which sometimes goes on for longer than two years although the strength of individual muscles does not increase.

These findings of Sharrard referred to paretic muscles i.e. muscles that are active however weak they may happen to be. The prognosis for recovery in completely paralysed muscles is quite different.

From the earliest days of disease, a certain proportion of muscles destined never to recover because they have completely lost their nerve supply. Others have retained a number of motor nerve cells, but are temporarily out of action.

Sharrard further showed that muscles that are paralysed at the end of first month 68 percent never recover, while the remainder will begin to function again with time and treatment.

Among muscles that are still paralysed at the end of fourth month 90 percent remain paralysed permanently, and at the end of sixth month this figure is raised to 95 percent. The 5 percent that do show some recovery after this seldom achieve more than a flicker of contraction. Thus the fourth month marks the end of the period after which a completely paralysed muscle may be expected to recover any useful function.

The destruction of motor cells in the spinal cord has been shown to occur regionally and focally (Elliott, 1942) and Sharrard, 1953). A consequence of this is that one

can know about the complete loss of all the motor cells supplying a muscle, if there is complete paralysis in muscles supplied by the same and adjoining spinal cord segments. Thus the presence of complete paralysis of the quadriceps ($L_{2,3,4}$) and tibialis posterior ($L_{4,5}$) indicates that a tibialis anterior (L_4) which is also completely paralysed is very unlikely to recover.

To sum up the whole process of recovery Sharrard gives a very beautiful example. In his words - "It is rather like the development of a negative in photography, but on a much longer time scale. During the first month the picture is quite unrecognizable; but between then and the fourth month, the main outlines appear. At the fourth month we can see what the picture is but it requires yet more time before the image becomes quite clear and the edges well defined. The picture is fully developed by the twelfth month; the patient has reached what is some times misnamed the chronic stage of poliomyelitis and each of his affected limbs shows a permanent pattern of paralysis.

DISTRIBUTION OF PERMANENT PARALYSIS

Though a striking feature of the paralysis that may result from an attack of poliomyelitis is its diversity, the belief that some order exists in the apparently irregular distribution of the permanent paralysis has been expressed by several authors. Wickman (1913) stated that "although a great variety of combination of paralyses

are found, certain types appear more often than others; in the leg the peroneal group and certain muscles of thigh-in my experience the quadriceps femoris especially-tend to be implicated".

At first sight the pattern seems to be different in every case and to be quite haphazard in its distribution but as Lovett (1915, 1917) and Legg (1929, 1937) described all is not quite as disorderly as it would seem to be.

Sharrard (1955) studied distribution of permanent paralysis in 149 patients. There were 2000 limb muscles that were either paralysed or paretic at the end of the period of recovery. He showed with the help of tables how frequently individual muscles were affected. The quadriceps, hip abductors and inner hemstrings were often affected, the leg muscles less often and the intrinsic muscles of the foot the least frequently affected. In the same group of patients the situation of muscles that had remained permanently paralysed was almost reversed. Tibialis anterior, tibialis posterior and the long flexors and extensors of the toes led in frequency, while the hip and thigh muscles were much less often paralysed. The intrinsic muscles of foot were, though, the least often paralysed as well as the least often affected.

Sharrard also determined the ratio of paralysis to paresis by tables which showed the susceptibility of each muscle to paralysis. The tibiales and long flexors and

extensors of the toes were very susceptible, the adductors and glutens maximus the least. Tibialis anterior was seven times as likely to be paralysed as the hip adductors or flexors and twice as likely to be paralysed as the peronei. According to him these were absolute values of considerable significance and can not be explained by the mechanism of chance.

AGE AND SEX DISTRIBUTION

The characteristics of the disease have altered and poliomyelitis can no longer be regarded as truely infantile. The change in age group of patients is illustrated by statistics in the state of massachusetts where in 1907 only seven percent of patients were over 15 years of age compared with 25 percent in 1947. Legg (1929) worked out age and sex incidence. According to him average age of patient was 5.4 years. The males predominated in all years except at four and five when the females predominated and at 10 when they were equal. Instances of more than one case in the same family occured 32 times in 755 families (4.2 percent). One family had four children affected.

Another study carried out by WHO in 1982 reveals - "All but four recipient cases were in patients under five years of age and 69 percent were in patients under one year of age. This age distribution was obviously related to immunization schedules which in all countries required the immunization of infant in the first year of life".

REGIONAL DISTRIBUTION

Jahss and Samuel (1917) studied 400 cases of anterior poliomyelitis and emphasized about regional distribution, a large number of cranial nerve involvement and muscle distribution.

Of the entire series 78 pefcent showed some involvement of lower extremities and 38 percent showed involvement of only one limb. Of this 10 percent were of upper extremity and 28 percent of the lower. In 20 percent of cases there was some form of trunk paralysis showing that it had been quite a common occurance. The right and the left sides of the body were equally attacked.

The extent of paralysis varied from a part of one leg to involvement of both legs, both arms, both sides of the abdomen and back and also the larynx.

In 13 percent of cases, the cranial nerves were involved. In six cases two different nerves were involved at the same time. The 5th nerve was affected, one time; the 6th nerve, one time; the 7th nerve, 38 times; the 10th nerve, four times and the 11th nerve, 13 times.

Lovett (1917) in his study of infantile paralysis concluded that most common involvement was of both legs, then one or the other leg, next in frequency all four extremities, then two legs and one arm, and then one arm. Next in frequency came a distribution of much importance - one arm and one leg - and here a hemiplegic arrangement

was distinctly more common than one arm and one leg on opposite sides.

In 948 patients over three years of age affected in 1916 epidemic, 72 percent were paralysed in the abdomen. According to Lovett these unique findings were undoubtedly because examination in every case was made as to this point. The examination for paralysis of the back was not as satisfactory or as accurate as most examination and slight degrees of weakness was apt to be overlooked. Back muscles involvement was 13.5 percent.

Neck paralysis has evidently been largely overlooked but frequently exists. In Lovett's study it was present in 11 percent of cases. The normal patient can lift the head against a small force when lying on the back. Weakness or paralysis of one or both sternomastoid muscles makes this impossible.

Legg (1929) noticed that the legs always show a much greater amount of involvement than the arms, with practically no difference between the right and left sides. Generally, too, the upper arm and the thigh show a greater amount of involvement. This however, did not hold true in regard to the severity of involvement. There was no great difference seen in the comparative severity of involvement of upper and lower arms. It was interesting that while the thigh shows a greater amount of involvement, the total paralysis in it is only 0.6 percent as compared to 7 percent in the leg.

PARTIAL VS TOTAL PARALYSIS

Lovett (1915) while commenting upon nature of the paralysis mentioned that partial paralysis was much more common than total. Of 1,452 muscles affected 416 were totally paralysed and 1,036 partly, that is, the relation of partial to total paralysis was as 2.5 to one. This ratio of partial to total paralysis varied in individual muscles.

A curious phenomenon was observed several times, where part of a muscle was paralysed and other part not. This was observed in deltoid muscle, where the anterior or posterior half might work independently of the other. Another muscle in which this was observed was pectoralis major, where the sternal and clavicular parts were separated by function.

The predominence of partial over total paralysis is of importance. According to Lovett, the reason for this would seem to lie in the grouping and relation of the nerve cells in the anterior cornua of the cord. These cells lie in logitudinal bundles, which are naturally largest in the cervical and lumbar enlargements.

He pointed out - "we must remember that the poison of infantile paralysis reaches the cord by means of the circulation and that the main blood supply is from the anterior spinal artery, horizontal branches from which enter the cord at each side at different levels, about

200 in number. The planes of destruction, therefore are likely to be transverse, while the lines of nerve centre association are longitudinal so that in the case of a muscle which derives its innervation from a group of nerve cells occupying several segments, a transverse lesion may well leave certain centres intact and some power may remain in the muscle".

This matter of partial paralysis is most important in the matter of treatment because in such muscles there remains some initiative and with it the power of developing more muscular volume and new association by repeated passages of impulses from brain to muscle.

SEVERITY OF PARALYSIS

According to Lovett's study, the muscles of the limbs nearest the trunk are more frequently affected than the distal ones; the left arm muscles are noticeably more frequently affected than the right. The leg muscles in the right and left leg are equally affected.

The facts of use or function are that the right arm is much more actively used than the left, not only more frequently, but also for more varied and complicated and finer movements. But the legs are equally used. It would therefore seem that muscles used actively, continuously and in a complicated way are more likely to escape than those less used, or used for simpler, less continuous work. Lovett presumed that the blood supply would be more

free around the spinal centres where the motor activity was greatest and most complicated and perhaps less free where the motion were less frequent and complicated. This would account for the predominence of left arm paralysis and the equal paralysis of both legs.

This also accords with the distribution of the paralysis in both arms and legs, which has been shown to be most frequent near the trunk. The demands on the hip and shoulder muscles are simple and less continuous than on the muscles of the lower leg and forearm or of the hand and foot. The latter are continuously active in small, fine complicated movements, whereas the larger muscles nearest the trunk deal with the coarser and less frequent movements. The relation between the activity of the proximal and distal parts of a limb are not unlike those of the left and right arms in their relative use. It seems probable from these facts and this grouping that on the whole muscle centres given to finer, complicated more frequent movements have a more active blood supply and are less likely to attack on their nerve centres by the virus of infantile paralysis than the centres of muscles functioning in heavier, less complicated and less frequent movements.

Lovett (1915) analysed 58 cases and pointed out about paralysis of arm muscles. In cases in which the muscles of upper extremity are involved without paralysis

occuring at other parts of the body, it is more severe in this region than when the muscles of the legs are also involved. Arm paralysis which is strictly regional is more severe than arm paralysis which exists in combination with more general paralysis.

Lovett concluded from his study and said that the investigtion of paralysis of the arm showed -

1. that the paralysis was most frequent at the shoulder and diminished in frequency from shoulder to the hand.

2. that the paralysis was severest in the shoulder and diminished as one went towards the hand.

3. that paralyses of the muscles of the left arm was very much more frequent than of the right arm.

With regard to paralyses of the muscles of lower limb the following facts were observed, which are of importance as contrasted with the similar observation in the arm :-

1. The paralysis was on the whole more frequent at the hip and diminished in frequency towards the foot; that is the individual muscles in the upper segment were more often affected than in the lower.

2. The paralysis was on the whole lightest in the hip, next lightest in the thigh and severest in the lower leg; that is, the proportion of total to partial paralysis increased as one went away from the hip towards the foot.

AFFECTION OF INDIVIDUAL MUSCLES

Lovett (1915) made tables to show the affection of individual muscles which shows that they were affected either partially or totally. The main facts are that the quadriceps, glutei and gastrocnemius lead in frequency and that paralysis of leg muscles is much more frequent than of arm muscles. Abdominal paralysis existed in more than half of all the cases and affection of the muscles of the spine in more than a quarter. The latter points have a distinct bearing on the occurance of scoliosis and indicate that such affections are more common than had been supposed. The cases of abdominal paralysis were always symmetrical with two exceptions one right and one left. This paralysis may occur as the only paralysis in the entire muscular system. When associated with paralysis of other parts, the association is always with leg muscles.

Sharrard (1955) obtained tables for lower limbs as well as for upper limbs. In frequency of affection the deltoid muscle led, followed by triceps and pectoralis major. The least affected muscles were the long flexors of digits; the intrinsic muscles of the hand were in the intermediate position. In frequency of paralysis the deltoid muscle came second to the thener muscles and was followed by interossei and the triceps; pectoralis major which was third in frequency of affection, now became

twelfth. On determining susceptibility to paralysis, the intrinsic muscles of the hand were the most susceptible followed by the muscles acting on the wrist. The deltoid muscle was only moderately susceptible and the least susceptible were trapezius and pectoralis major.

Sharrard studied 2464 affected muscles, of these 1,502 were paretic and 962 paralysed. The ratio of paresis to paralysis was 1.56 to one.

The numbers of parases and paralyses of individual muscles, and the proportion of paresis to paralysis varied. The main facts were that the quadriceps and the hip abductors (Gluteus medius and minimus) led in frequency of affection and in numbers of pareses, but the muscles of the leg were the most frequently paralysed. Tibialis anterior, tibialis posterior and the long flexors and extensors of the toes showed low proportions of paresis to paralysis, while the hip flexors and hip adductors showed a high proportion.

The order of the muscles shown in tables by Sharrard confirmed the findings of Lovett (1915) that the muscles nearest the trunk are more frequently affected than the distal ones. He observed "the demands on the hip and shoulder muscles are simple and less continuous than on the muscles of the lower leg and forearm or of the hand or foot. The latter are continuously active in small, fine and complicated movements".

It is tempting on this basis to assume that a casual relationship exists between differences in the size and function of individual muscles and their frequency of affection.

When, however, the same muscles are arranged in order of frequency of paralysis, the picture is completely different. The largest number of paralyses are found in the distal muscles, which also agrees with Lovett's findings. To explain them he states - "the severity of the paralysis is proportionate to the weight to be met by the muscles at different levels, not because this factor influences in any way the original affection of the nerve cells but because it may retard the recovery of those muscles working against the greatest weight".

But this hypothesis fails to explain several important discrepancies. There is very low incidence of paralysis in the intrinsic foot muscles which by Lovett's reasoning, should be the most frequently paralysed of all muscles in the lower limb. The number of paralysed inner hamstring muscles - differs from the number of paralysed biceps femoris muscles, though it should be about the same. Further, the rate of recovery in proximal and distal muscles has been shown to be the same for all muscles in the lower limb instead of showing any differences needed to account for the complete dissimilarity between the order of the muscles

in tables (Sharrard 1955).

As Skinhj (1949) observed in a similar study there is no quality of the muscles such as size, function, position in the limb or phylogenetic development that can satisfactorily explain the frequent affection of some muscles and the high proportion of paralysis in others.

Not much work has been done in India on this particular subject. Punetar and Patel (1977) however, studied the pattern of residual paralysis in poliomyelitis of lower limbs in Ahmedabad. According to them it was found that while the quadriceps, hip extensors and tibialis anterior were most frequently affected, the flexor hallucis longus and flexor digitorum longus were involved least frequently.

On the other hand, in the paralytic group tibialis anterior, quadriceps and tibialis posterior were most commonly affected and the tensor fascia femoris involved least commonly.

The segmental distribution of muscles affected and muscles paralysed show that while lumbar two and three were most frequently affected, lumbar four was most commonly involved in complete paralysis. While commenting the susceptibility of a particular muscle to paralysis they told that tibialis anterior, tibialis posterior and quadriceps were very susceptible, while abductors of hip

and tensor fascia femoris were the least.

Infantile poliomyelitic paralysis has been regarded as a haphazard affection of muscles, most frequent in the leg. In the cord lesion it appears to have a purely accidental distribution most marked in the lumbar enlargement. It is possible, however, that there are other factors than the cord lesion which determine the ultimate condition of affected muscles.

ANALYSIS OF SEVERITY DISTRIBUTION IN ARM AND LEG

Another interesting findings observed by Lovett (1915) was that the muscles of the upper extremity are more severely affected nearest the trunk and less severely lower down. But this relation is reversed in the leg and the largest proportion of severe paralysis is in the lower leg and foot. This is estimated on the proportion of total to partial paralysis in the individual muscles.

This puzzling phenomenon is more nearly correlated to the weight comming on each muscle in the activities of the upright position than to any other factor. The great majority of these patients were walking in some form or other so that the weight bearing position may fairly be taken into account.

At the shoulder, the deltoid, triceps and biceps all help to hold the arm up against the shoulder joint. The weight to be met is not only in this suspensory function, but also in attempted movements. It is greatest

at the shoulder and less as one goes down the arm, because the weight of the whole arm is obviously more than the weight of the lower one or two segments. Upper arm muscles consequently, have more weight to handle than forearm and hand muscles.

In the leg, on the other hand, the weight to be met in muscular function increases as we go from the hip to the feet. There is greater superincumbent weight at the lower leg than at the hips, so that the lower leg muscles raise more weight than hip muscles in walking. There is of course, no proof that this variation in severity of paralysis is caused by this greater or less weight to be met in muscular function. However, the explanation accords with the facts better then any other seems to do.

Severity distribution can not be correlated with size of muscles or function of a peculiar sort. It can not be explained by local circulatory sluggishness affecting dependent parts. It is not associated with anterior or posterior muscles nor is easy to correlate it with spinal localization.

It seems purely a segmental limb distribution and whether it is or is not correct explanation, severity of paralysis is proportionate to the weight to be met by the muscles of different levels. This factor does not influence the original affection of the cells in any way but it may retard the recovery of those muscles working against the greatest weight.

SEGMENTAL INNERVATION IN RELATION TO AFFECTION OR PARALYSES OF MUSCLES

Sharrard tells if the paralysis in a muscle is not related to any feature of the muscle itself, there remains the possibility that it may be related to its innervation, or, more precisely, to the site and extent of changes in the motor cells of the anterior horn of the spinal cord.

Evidence of such a relationship is given by an enquiry into the segmental incidence of muscle affection. For each spinal segment, the total number of affected muscles that recieve a supply from the segment were noted, thus, in the third lumbar segment, the muscles were the hip flexors, the hip adductors and quadriceps. The mean number of affected muscles - in this segment was calculated and used to plot a curve, which represented the segmental incidence of muscle affection. The highest incidence was found in the second and third lumbar segments; below this level, there is a uniform decrease in the numbers of affected muscles that successive spinal segment supply.

The segmental incidence of paralysis, derived in the same way, is altogather different. It is included for comparison with an almost identical curve obtained in the same way by Seddon et al (1945) in an analysis of a large number of cases of poliomyelitis in the Malta

epidemic of 1942-43. A high incidence was found in all spinal segments between the 4th lumbar and the second sacral segments. The curve was irregular and indicated no direct relationship between segmental innervation and frequency of paralysis.

Attempts by earlier authors (Lovett, 1915, Skinhøj, 1949) to explain similar findings in terms of spinal cord lesion were hampered by the paucity of information concerning the localization of function in the motor cells in man and by the incomplete accounts of the sites by destruction of these cells in poliomyelitis.

THE SITES OF MOTOR CELL DESTRUCTION IN POLIOMYELITIS

A method of reconstruction by projection microscopy of the nerve cell content of the lumbosacral spinal cord was deviced by Sharrard (1953).

The general distribution of motor cell destruction in the anterior horns of poliomyelitic spinal cords showed several constant features.

The second and third lumber spinal segments were the most frequently and extensively attacked in all the cords. Segments caudal to this were less affected, the third and fourth sacral segments, being specially likely to be spared. A similar segmental incidence of motor cell destruction has been noted by others (Horanyi-Hechst, 1935, Peers 1943, Elliot 1945, 1947).

Destruction was found not to be diffuse but localized in discrete foci of varying length and width with interposed lengths of grey matter of more normal cell content. In the transverse plane the centre of the anterior horn appeared to be the most vulnerable area at most segmental levels.

Motor cell destruction was always much more severe than would have been expected. One case in which there had never been any demonstrable weakness in any muscle in the lower limbs had suffered losses of upto 40 percent of the normal number of cells in some cell columns. Far from these being any evidence that residual motor cells were functionally inactive, it was surprising to discover how small a proportion of cells had been required to produce a useful contraction in the muscle they supplied. The residual power of a muscle was found to be closely related to the proportion of remaining motor cells that supplied it.

Muscle power (MRC Scale)	Percentage of residual motor cells
0	0 - 2
1	2 - 3
2	3 - 5
3	5 - 10
4	10 - 20
4	20 - 40
5	Over 40

The relationship between muscle power and residual motor cells in the spinal cord.

THE RELATIONSHIP BETWEEN THE DISTRIBUTION OF THE PARALYSIS AND THE DESTRUCTION OF MOTOR NERVE CELLS

The segmental incidence of muscle affection derived from the analysis of the clinical material (Sharrard 1953) agrees exactly with the general distribution of motor cell destruction. Since the upper lumbar spinal segments supply muscles in the region of the hip and thigh, while the lower lumbar and sacral segments generally supply the muscles of the leg and foot, it is easy to see why there is, apparently a greater incidence of affection in proximal than in distal muscles in the limb. It is interesting to note that the hip muscle that derives its main supply from the sacral segments i.e. the gluteus maximus - is less frequently affected than other hip muscles. This is also true of the small external rotator muscles of the hip.

The findings of Sharrard (1953) in the spinal cord also account for the large number of paralyses found in muscles such as tibialis anterior, tibialis posterior and the long flexor and extensor muscles of the toes. Muscles supplied by short columns of cells are the most frequently paralysed. Those supplied by long columns are more likely to be paretic. The high incidence of paralyses in muscles supplied by the lower lumbar and upper sacral segments is due to the fact that most of them - tibialis anterior, tibialis posterior, peronei and the long muscles of the toes are supplied by short columns.

There is yet no adequate explanation for the greater incidence of motor cell destruction in the upper lumbar segments and the progressively smaller incidence more caudally. In the transverse plane, the central sites of cell loss also found by Elliot (1945, 1947) in the anterior horn, resemble those found by Krogh (1945) in experimental hypoxaemia of the spinal cord, and it is possible that vascular factors are partly responsible for them.

ASSOCIATED PARALYSIS

That certain muscles appear to be paralysed or weakened togather has been noted by several authors (Courtney 1896, Wickman 1913, Lovett 1915). Their observations were unfortunately incomplete and relied on clinical impressions rather than on numerical analysis.

Lovett (1915) observed the muscles in the leg most closely associated functionally are the gluteals, the quadriceps and the gastrocnemius, for they are the muscles which maintain the upright position. The gastrocnemius holds the tibia upright on the foot, the quadriceps hold the knee straight and the gluteals hold the trunk erect on the legs. The associations were as follows :-

If the quadriceps is paralysed, either the gluteals or the gastrocnemius or both are almost always associated with it. In 109 cases there were only two exceptions. In three cases the quadriceps had no association in the leg. In the 109 cases of quadriceps paralysis, to contrast with

the 106 associations of gluteals or gastrocnemius, there were only 58 associations of paralyses of one or both hamstrings. The quadriceps, therefore, is affected nearly twice as often with its associated muscles as with its antagonist.

When the gastrocnemius is involved, the quadriceps or gluteals were involved in 108 out of 109 cases; but the antagonist of the gastroenemius, the extensor digitorum longus and the tibialis anterior, either one or both, were paralysed in combination with it in only 66 cases.

Jahss (1917) studied 400 cases of anterior poliomyelitis of 1916 epidemic and commented about association of paralysis :- "the most frequent combination of muscles attacked in the leg has been those supplied by the anterior tibial nerve". In the thigh, the quadriceps, adductors and hamstrings have shown a distinct tendency to be involved togather (a mixture of both the lumbar and sacral plexuses)".

When the external rotators of the hip were involved the internal rotators always, accompanied them. In no case were they affected alone. In the arm, the deltoid, pectoralis major and latissimus dorsi have been associated in paralysis. The latissimus dorsi was affected in 51 cases and in 50 of these the foregoing took place. The upper arm type or the forearm type of paralysis did not occur in any instance.

Sharrard (1955) reviewed the muscle charts of the 203 lower limbs to find out whether those impressions were correct and to reveal associations of paralysis that might otherwise be overlooked. Coincident sparing or absence of paralyses in muscles, which is equally important and likely to escape clinical observation, was also noted.

Some associated paralyses for instance between the long toe extensors and the peronei or between the hip abductors (Gl. medius and minimus) and the gluteus maximus - might be explained by the closely allied functions of the muscles, as had been suggested by Lovett (1915). Other associations such as those between the calf muscles (Triceps surae) and the biceps femoris (first described by Bennett in 1952) or between quadriceps, the hip adductors and the hip flexors can not be explained so easily.

The absence of a strong association between the inner hamstring muscles and the biceps femoris or between the long toe flexors and the intrinsic foot muscles provides further evidence against the theory that associated function leads to associated paralysis of muscles.

Punatar and Patel (1977) could draw the same results during their study and found that certain muscles have a tendency to be spared or paralysed together. These associations most probably depend on the position

of the spinal nuclei of the muscles. In their study a surprising association was found between the paralysis of flexors of hip and internal rotators. If one of these was paralysed then in 7 out of 10 cases the other was likely to be paralysed. On the other hand, some muscles with a common nerve supply like hip abductors and extensors did not have associated paralysis.

EXPLANATIONS OF PREDOMINANCE OF ASSOCIATION PARALYSIS

According to Lovett (1915) this predominance of paralysis is susceptible of several possible explanations, of which the following may be mentioned :

1. The muscles which maintain erect posture are all very large and must have large centres composed of many motor cells. On account of this, they are more likely to be affected than smaller muscles by a generally distributed destructive process in the cord. But this is not altoga-ther acceptable because the tibialis anterior and peronei, which are small, are of high incidence. Reciprocal to this the pectoralis major a large muscle is of low incidence.

2. The second explanation given by Lovett is that associated muscles may be so intimately grouped in the arrangement of their motor centres in the cord that they are more likely to be involved in the same lesion than opposed muscles would be.

3. The third explanation for the predominance of residual paralysis in associated rather than antagonistic

groups may be in the functional relation of the muscles themselves. Three muscles, the glutei, the quadriceps and the gastrocnemius work togather to maintain the upright position, if a whole leg is lightly affected, it may be that the association of these muscles in function may retard their recovery by their intimate and necessary functional dependence on each other. Especially if one of these muscle were seriously affected, it might retard the recovery of muscles associated with it by throwing more work on them than they were able to perform in their affected condition.

Sharrard (1955) explained about association of paralysis when the whole of the motor column that supplied a muscle had been destroyed, it was likely that one or more adjacent motor columns that occupied the same length of spinal cord was completely destroyed or severely affected. This is reflected in clinical distribution of muscle paralysis. For example, the columns that supply extensor hallucis longus, extensor digitorum longus and peronei lie next to each other and occupy approximately the same length of spinal cord. Therefore, paralysis of one of these muscles is frequently associated with paralyses of the other two. Conversly absence of paralysis in one muscle is likely to be associated with absence of paralyses in the others.

ASSOCIATED PARALYSES IN THE LOWER LIMB
(Table given by SHARRARD)

Muscle	Associated muscles
Hip flexors (psoas)	Quadriceps, abductors
Abductors	Quadriceps, inner hamstring muscles, hip flexors
Quadriceps	Hip flexors, adductors, inner hamstring muscles
Inner hamstring muscles	Adductors, quadriceps, hip abductors
Hip abductors (gluteus medius and minimus)	Gluteus maximus, biceps femoris, tensor faciae latae
Tensor fasciae latae	Hip abductors, gluteus maximus
Gluteus maximus	Hip abductors, biceps femoris, tensor faciae latae
Biceps femoris	Gluteus maximus, hip abductors, calf muscles
Calf muscles (triceps surae)	Biceps, femoris, flexor digitorum longus
Flexor hallucis longus	Flexor digitorum longus, extensor hallucis longus
Flexor digitorum longus	Flexor hallucis longus, extensor hallucis longus
Extensor hallucis longus	Extensor digitorum longus, peronei, flexor hallucis longus
Extensor digitorum longus	Extensor hallucis longus, peronei
Peronei	Extensor digitorum longus, extensor hallucis longus
Tibialis posterior	Tibialis anterior, extensor hallucis longus
Tibialis anterior	Tibialis posterior
Intrinsic foot muscles	Calf muscles, peronei

Unusal associations, like that between the calf muscles (Triceps surae) and the biceps femoris, can be accounted for in the same way, since their motor cell columns are so closely associated. The factor common to all strongly associated pairs of muscles is that their motor cell columns lie adjacent to one another and their segmental levels of supply correspond or overlap.

ASSOCIATED PARALYSIS AND THE PROGNOSIS FOR PARALYSED MUSCLES

In another paper Sharrard (1955) has shown the prognosis for a paralysed muscle to be related to the degree of paralysis in the muscles supplied by the same spinal segment. Associated paralysis between muscles may also be applied to determine prognosis for recovery.

Ten muscles were chosen in which it may be important to know the prognosis for recovery. The probability of recovery to a functional power (MRC grade 2 or greater) was worked out for each muscle -

1. When both of its most strongly associated muscles were paralysed.
2. When one associated muscle was paretic or normal and the other paralysed, and
3. When both associated muscles were paretic or normal.

When both associated muscles were paralysed, the prognosis was very bad, particularly for the quadriceps,

the hip abductors, tibialis anterior, tibialis posterior and the long toe extensors. When both associated muscles were paretic or normal there was an excellent prognosis for all muscles - except tibialis anterior.

MATERIAL AND METHODS

MATERIAL AND METHOD

Two hundred and ninty patients who suffered disability due to permanent paralysis as a result of poliomyelitis, were received at orthopaedics out patient department, M.L.B. Medical College hospital, Jhansi and at District Hospital, Jhansi between July 87 and June, 88.

All the cases of poliomyelitis having residual paralysis for one year or more were the subject of present study. Average age group of patients included in this study was 13.2 years. The patients were of either sex, irrespective of their profession and socio-economic status.

In the present study a concerted effort has been made to demonstrate the pattern of muscle distribution in post polio residual paralysis patients, if any.

CRITERIA FOR SELECTION OF CASES

Patients having poliomyelitis of less than one year duration were not included in this study. Only those having residual paralysis for one year or more were the eligible candidates.

DIAGNOSIS

A short history about the onset of paralysis, age of involvement and extent of paralysis with symptoms at the time of acute attack of poliomyelitis was taken. Whether the child was walking before the onset of paralysis or not was also enquired.

(i) Preparalytic stage of poliomyelitis

The illness is usually of vague and variable duration. It may last from a few hours to few days, and one to three days is the usual duration. Acute attack of poliomyelitis may be quite severe or so mild as to pass unnoticed. It is usually but not always followed by an asymptomatic stage before the onset of paralysis. Many patients never progress beyond this stage and are only diagnosed by the laboratory findings of the polio-virus in the throat or stools.

The importance of this stage is that exercise, injection or operation may precipitate severe paralysis in the limbs exercised or traumatized.

(ii) Sign and symptoms

The history given by patients is variable and vague and mimic other viral infections such as influenza. The more common sign and symptoms are :-

(a) Headache and malaise.
(b) Sore throat and upper respiratory tract infections.
(c) Slight cough.
(d) Diarrhoea or constipation.
(e) Backache and joint pains.
(f) Pyrexia of variable duration and severity.
(g) Mild neck stiffness.

Many other symptoms may occur, and the only safe way to deal with the problem is to regard all children

with above symptoms as suspects during an epidemic.

TESTING OF MUSCLE POWER AND MUSCLE CHARTING

Each patient was examined at the out patient department. A complete muscle test was performed on each occasion. So far as possible testing was made in a warm room (i.e. with adequate temperature), after rest.

Standard methods of muscle testing were used (Kendall and Kendall, 1971, Daniels Williams and Worthinghom, 1947). Each muscle was allowed to contract three times, through the greatest range of movement of the joint concerned. The grade recorded depended upon the power of muscle in the third of three contractions.

The scale of muscle power ranging from 0 - 5 recommended by the Medical Research Council was used during making of the observations. All the tests of muscle power were made by the same person (myself).

Grade 0 = Complete paralysis.

1 = A flicker of contraction only.

2 = Power detectable only when gravity is excluded by appropriate postural adjustment.

3 = The limb can be held against the force of gravity, but not against examiner's resistance.

4 = There is some degree of weakness, usually described as poor, fair or moderate strength.

5 = Normal power is present.

The detailed examination of patient regarding the muscle power was made. Findings observed during examination were recorded in the proforma as in annexure-I.

THE ACCURACY OF MANUAL MUSCLE TESTING

The estimation of muscle power by manual methods has been the subject of some criticism by those who advocate a return to mechanical methods of measurement of muscle power (Russell, 1952) - notably that, in the assessment of the power of a muscle, it is not certain that two observers will assign the same grade to it.

In most muscles and muscle groups the Medical Research Council Scale can be used to give an unequivocal result. An incorrect assessment is almost always either due to ignorance of the method, in attention to detail, lack of appreciation of the action of the muscle under test or the deception by the trick action of another muscle. A high degree of objectivity is necessary in manual muscle testing.

Ideally, muscle tests should be made by a single person. The assessment of the power of certain muscles. Such as the muscles that act upon the digits, is difficult to make in the exact terms of the Medical Research Council Scale and is partly dependent on the pure judgement of the particular observer; even so, the assessment of the observer should be consistent.

EVALUATION OF RESULTS

Simple mathematical calculations were done. Statistics was used to work out associated paralysis. Each muscle or muscle group was paired with every other muscle. X^2-test was applied repeatedly. Differences between the expected and the observed findings were worked out and submitted to statistical analysis.

OBSERVATIONS

OBSERVATIONS

In present study a total of 290 patients of post polio residual paralysis was included for detailed clinical examination of muscle power. The patients were of both sex and different age groups.

Table - I

Showing male, female ratio of study group

Sl. No.	Sex	Number	Percentage (%)
1.	Males (M)	224	77.2
2.	Females (F)	66	22.8
	Total	290	

Male female ratio was - 3.4:1

Table - II

Age incidence of study group

Sl. No.	Age group in years	Number of cases	Percentage (%)
1.	2 - 3	15	5.1
2.	3 - 4	08	2.7
3.	4 - 5	14	4.8
4.	5 - 10	90	31.0
5.	10 - 20	117	40.3
6.	20 - 30	35	12.0
7.	30 - 40	10	3.4
8.	> 40	01	0.3
	Total	290	

Maximum number of cases included for study were from 10 - 20 years of age group. Average age of study group was 13.2 years.

Table - III

Showing age of involvement

Sl. No.	Age of involvement in years	No. of cases	Percentage (%)
1.	$<$ 1	167	57.6
2.	1 - 2	69	23.8
3.	2 - 3	24	8.3
4.	3 - 4	13	4.5
5.	4 - 5	10	3.4
6.	5 - 10	06	2.1
7.	$>$ 10	1	0.3

Patients or their parents were enquired about the age of involvement i.e. the age at which disease commenced. Maximum age at which poliomyelitic involvement occured was 12 years.

Highest incidence of involvement was among less than one year of age group.

Table - IV

Showing involvement of upper extremity

Total number of affected upper limbs = 16

	Involvement of left upper limb	Involvement of right upper limb	Bilateral upper limb involvement
Number of cases	13	02	01
Percentage	81.25	12.50	6.25

Table - V

Showing involvement of lower extremity

Total number of affected lower limbs = 280

	Involvement of left lower limb	Involvement of right lower limb	Bilateral lower limb involvement
Number of cases	100	120	60
Percentage	35.71	42.85	21.42

A total of 16 patients were having upper limb involvement as compared to 280 patients of lower limb involvement. It was surprising to note that out of 16 affected upper limbs 13 were of left sided involvement, while in 2 cases right side was affected, rest one case was of bilateral involvement.

This specific pattern of left sided involvement was not present in case of lower limb paralysis as they were involved almost equally.

Table - VI

Regional distribution of involvement

Sl. No.	Involved extremity	Number of cases	
1.	Unilateral lower limb	220	= 280 (Total lower limb involvement)
2.	Bilateral lower limb	60	
3.	Unilateral upper limb	15	= 16 (Total upper limb involvement)
4.	Bilateral upper limb	01	
5.	Upper with lower limb	05	
6.	All extremities	01	
7.	Trunk	00	

Out of 290 cases which were examined, only 16 cases were of upper limb involvement and out of these 16 cases only 10 were those in which only upper limb involvement was present. Rest six cases were having upper as well as lower limb involvement. Not a single case was obtained of trunk paralysis. One case was having paralysis was 7th cranial nerve.

Eighteen muscles/muscle- groups of lower limb were included for muscle charting. Total number of muscles of lower limb examined were 10080 in number.

Total number of affected lower limbs was 340 (out of examined 560 lower limbs) and in these 340 affected limbs 4435 muscles were involved which were labelled as paretic or paralytic according to their residual muscle power.

Table - VII

Incidence of affection (in order of frequency of affection)

Sl. No.	Muscle	Number of affected muscles
1.	Hip flexors	318
2.	Quadriceps	304
3.	Hip abductors	288
4.	Tibialis anterior	288
5.	Hip adductors	287
6.	Inner hamstring	278
7.	Biceps femoris	278
8.	Hip extensors	277
9.	Medial rotators	264
10.	Lateral rotators	258
11.	Tibialis posterior	258
12.	Peronei	241
13.	Triceps surae	236
14.	Extensor digitorum longus	182
15.	Extensor hallucis longus	181
16.	Flexor digitorum longus	166
17.	Intrinsic muscles of foot	166
18.	Flexor hallucis longus	165
	Total	4435

All affected muscles of lower limbs were arranged in order of frequency of affection. Hip flexors rank first in the table which are followed by quadriceps, hip abductors, tibialis-anterior and hip-adductors. Intrinsic muscles of

table showing their least involvement.

Table - VIII

Incidence of paralysis (in order of frequency of paralysis)

Sl. No.	Muscle	Number of paralysed muscles
1.	Quadriceps	142
2.	Tibialis anterior	119
3.	Hip adductors	97
4.	Hip flexors	94
5.	Hip extensors	92
6.	Tibialis posterior	78
7.	Peronei	71
8.	Inner hamstrings	64
9.	Biceps femoris	64
10.	Medial rotators	61
11.	Lateral rotators	61
12.	Hip abductors	57
13.	Triceps surae	50
14.	Extensor hallucis longus	24
15.	Extensor digitorum longus	20
16.	Flexor hallucis longus	12
17.	Flexor digitorum longus	08
18.	Intrinsic muscles of foot	08
	Total	1122

When arranged in order of frequency of paralysis, quadriceps was paralysed in maximum number of lower limbs. Tibialis anterior was second which was followed by hip adductors, hip flexors and hip extensors. Distal group

of muscles were amongst least paralysed. Total number of paralysed muscles of lower limb was 1122 out of 4435 affected muscles.

Table - IX

Susceptibility to paralysis (in muscles of lower limb)

Sl. No.	Muscles	No. of paralysed muscles	No. of paretic muscles	Ratio of paresis to paralysis
1.	Quadriceps	142	162	1.14
2.	Tibialis anterior	119	169	1.42
3.	Hip adductors	97	190	1.95
4.	Hip extensors	92	185	2.01
5.	Tibialis-posterior	78	180	2.30
6.	Hip flexors	94	224	2.38
7.	Peronei	71	170	2.39
8.	Lateral rotators	61	197	3.23
9.	Medial rotators	61	203	3.32
10.	Inner hamstrings	64	214	3.34
11.	Biceps femoris	64	214	3.34
12.	Triceps-surae	50	186	3.72
13.	Hip abductors	57	231	4.05
14.	Extensor hallucis longus	24	157	7.54
15.	Extensor digitorum longus	20	162	8.10
16.	Flexor hallucis longus	12	153	12.75
17.	Flexor digitorum longus	08	158	19.75
18.	Intrinsic muscles of foot	08	158	19.75
	Total	1122	3313	2.95:1

The susceptibility to paralysis of each muscle is inversly proportional to ratio of paresis to paralysis. The lower the ratio, higher are the chances of paralysis. The quadriceps and tibialis anterior are amongst most susceptible to paralysis, while flexor digitorum longus and intrinsic muscles of foot are among least susceptible.

Table - X

Extent of paralysis

Sl. No.	Involvement of	Number of limbs
1.	Hip (alone)	09
2.	Knee (alone)	03
3.	Ankle (alone)	03
4.	Hip with knee	26
5.	Hip with ankle	13
6.	Knee with ankle	17
7.	Hip with knee with ankle	270

Involvement of different muscles acting on different joints of lower limb was worked out. Table shows that diffuse involvement of whole lower limb was much more common as compared to various joints independently.

Table - XI

Severity of paralysis in lower limb

Sl. No.	Region of involvement	No. of limbs
1.	Hip	318
2.	Knee	316
3.	Ankle	303
4.	Distal group of muscles*	186

*Flex. dig. longus, Flex. hal. longus, Ext. dig. longus, Ext. hal. longus, Intrinsic muscles of foot.

Above results are worked out from previous table, showing severity of paralysis in lower limb. Hip was involved in maximum number of cases. One special feature was that distal group of muscles was least involved. Out of 340 affected limbs, there were 154 cases in which distal group of muscles was spared.

Table - XII

Associated paralysis

Sl. No.	Muscle	Associated muscles
1.	Hip flexors	Hip extensor, knee flexors, quadriceps.
2.	Hip extensor	Tibialis anterior, hip flexors, knee flexors.
3.	Hip abductors	Hip adductor, hip extensor, triceps surae.
4.	Hip adductors	Hip abductors, hip-extensor, peronei
5.	Quadriceps	Knee flexors, hip-flexors, tibialis-posterior.
6.	Knee flexors	Hip flexors, quadriceps,triceps surae
7.	Triceps surae	Hip extensor, intrinsic muscles of foot, flexor digitorum longus, peronei
8.	Tibialis anterior	Hip extensor, tibialis posterior, quadriceps, hip-flexors.

Each muscle or muscle group was compared with rest of muscles in lower limb. Their association was worked out with the application of X^2 test.

<u>Figure - 1</u>

Figure-1 shows histogram indicating segmental incidence of affection. On horizontal X-axis spinal segments are taken while on vertical Y-axis is mean number of affected muscles. Mean number of muscles affected in different spinal segments was worked out. The results were as follows :

L1 - 318	L4 - 256	S1 - 249
L2 - 303	L5 - 240	S2 - 219
L3 - 303		

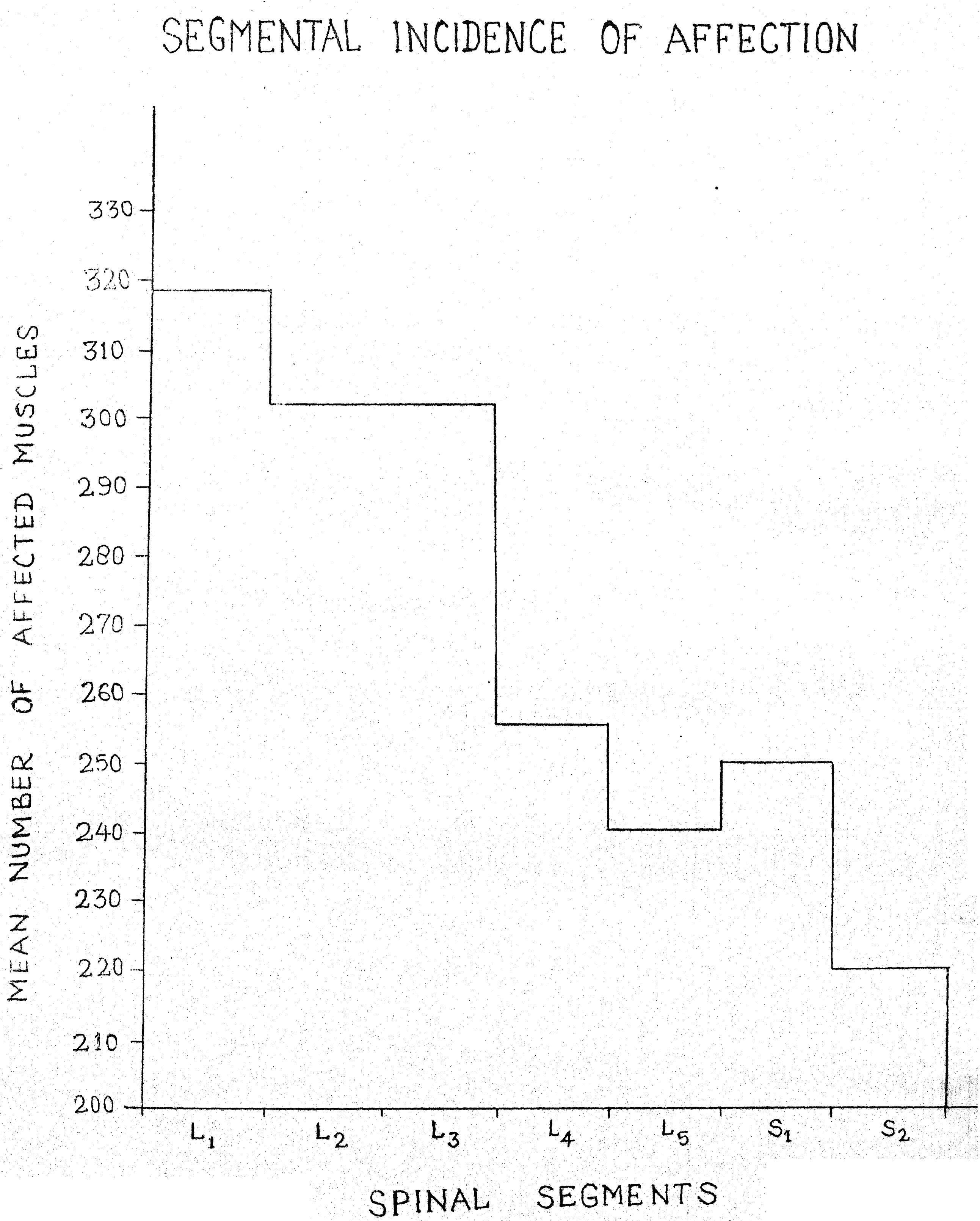
Histogram shows clearly that lumbar one spinal segment was most frequently affected followed by lumbar two and three. Sacral two was least frequently affected.

<u>Figure - 2</u>

Figure shows segmental incidence of paralysis. Second and third lumbar spinal segments were most frequently paralysed followed by first lumbar spinal segments. First and second sacral spinal segments were among the least frequently paralysed.

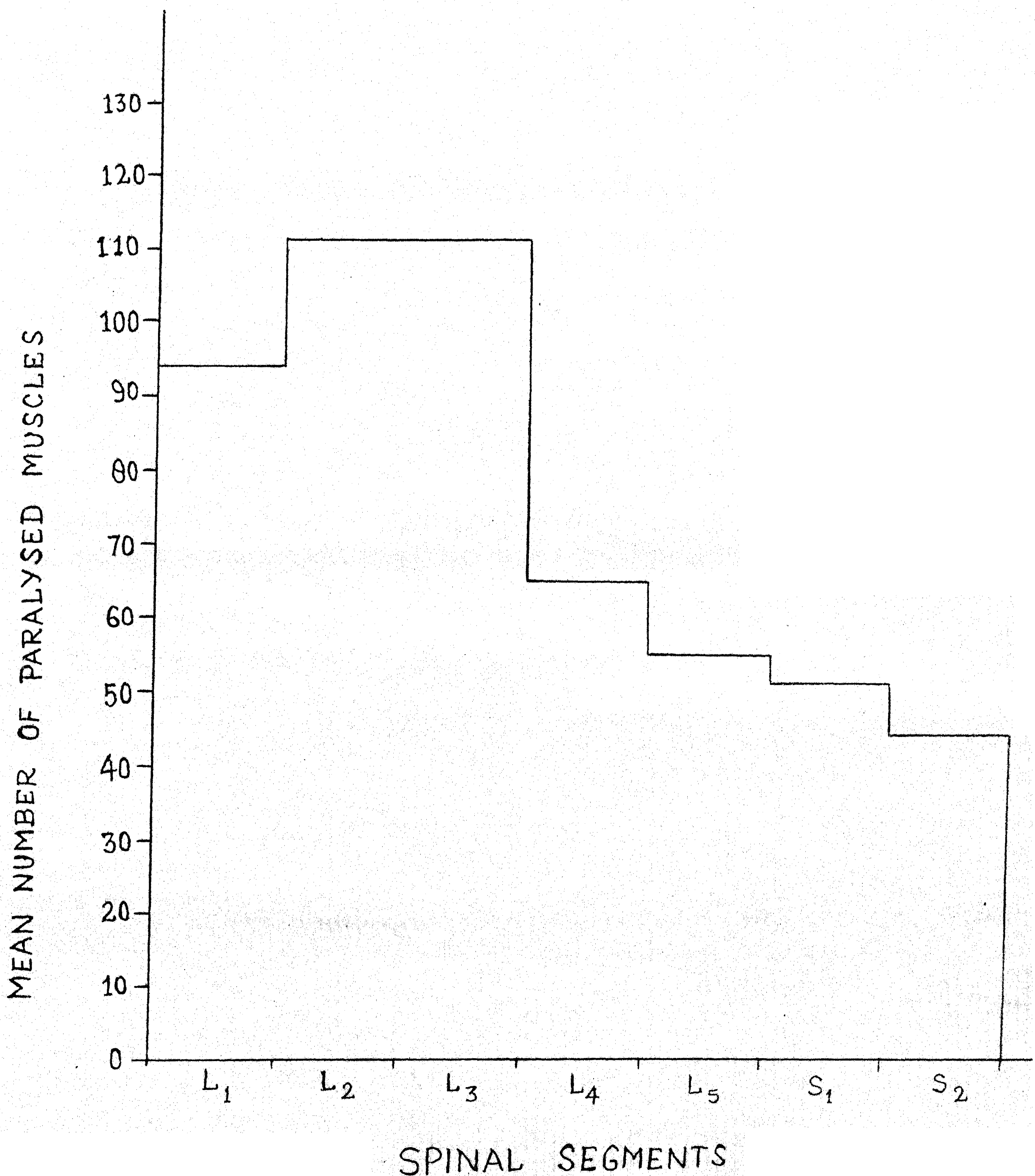
Mean number of paralysed muscles was :

L1 - 94	L4 - 66.2	S1 - 52.5
L2 - 111	L5 - 55.2	S2 - 44
L3 - 111		


SEGMENTAL INCIDENCE OF AFFECTION
MEAN NUMBER OF AFFECTED MUSCLES
330
320
310
300
290
280
270
260
250
240
230
220
210
200
L_1
L_2
L_3
L_4
L_5
S_1
S_2
SPINAL SEGMENTS

(FIGURE - 1)

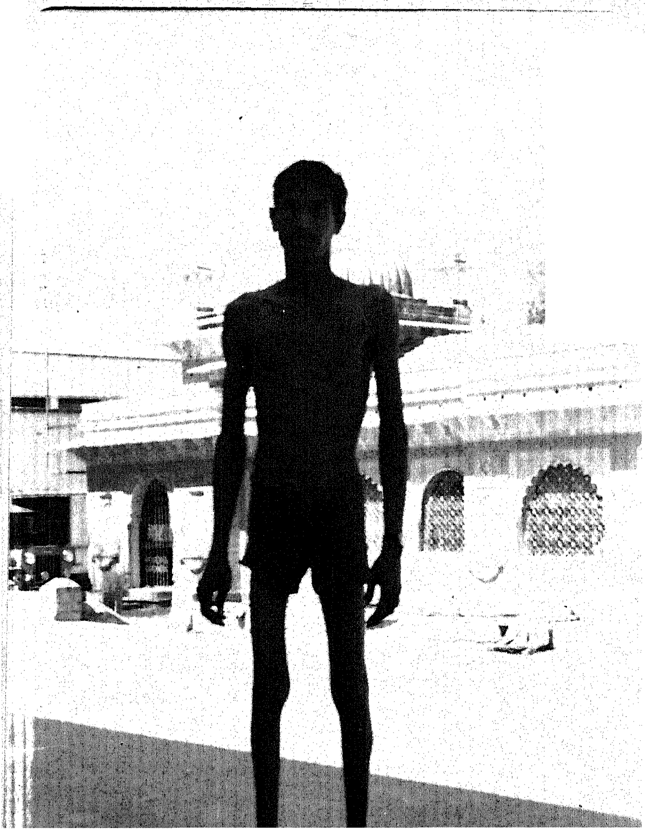
SEGMENTAL INCIDENCE OF PARALYSIS

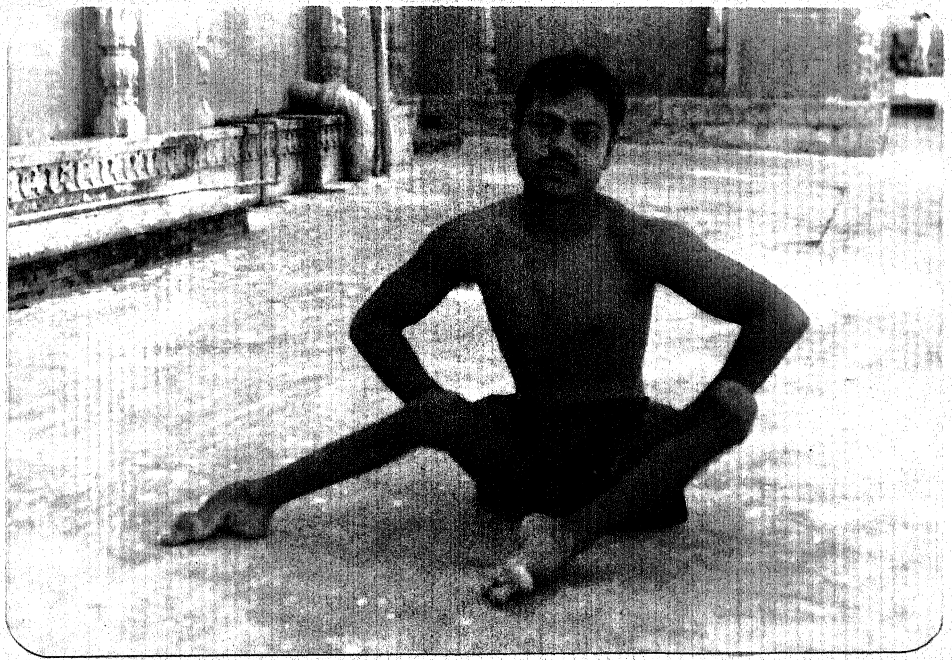


(FIGURE - 2)

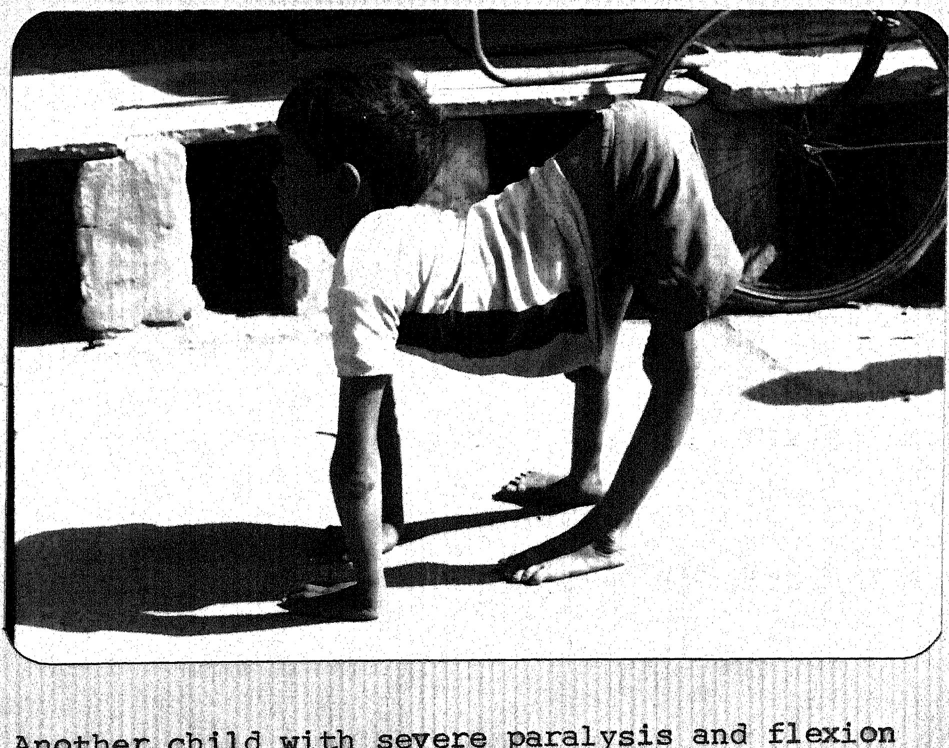
Male aged 18 years showing paretic right quadriceps and tibialis anterior. Compensatory over-activity of long extensors of toes leads to early clawing.

Bilateral gross evertor insufficiency - more on left side with equino-cavo varus of foot and ankle and severe clawing of toes.

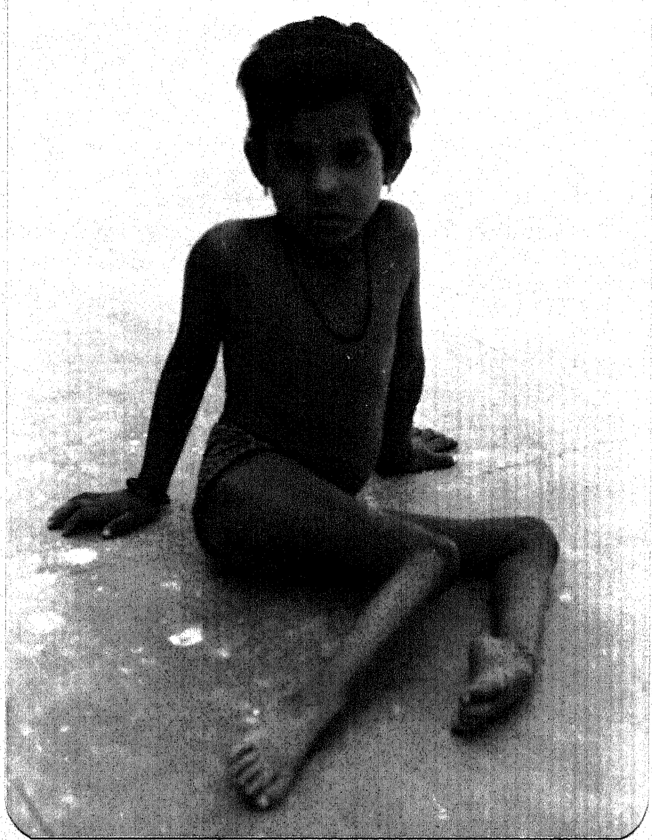




Bilateral paralysis of hip and knee extensors with contracture of iliotibial band giving rise to flexion and abduction deformity at hips and flexion at knees. Severe forefoot equino-cavus and clawing of toes on right side. Equino-cavo-varus with clawing of toes on left side.

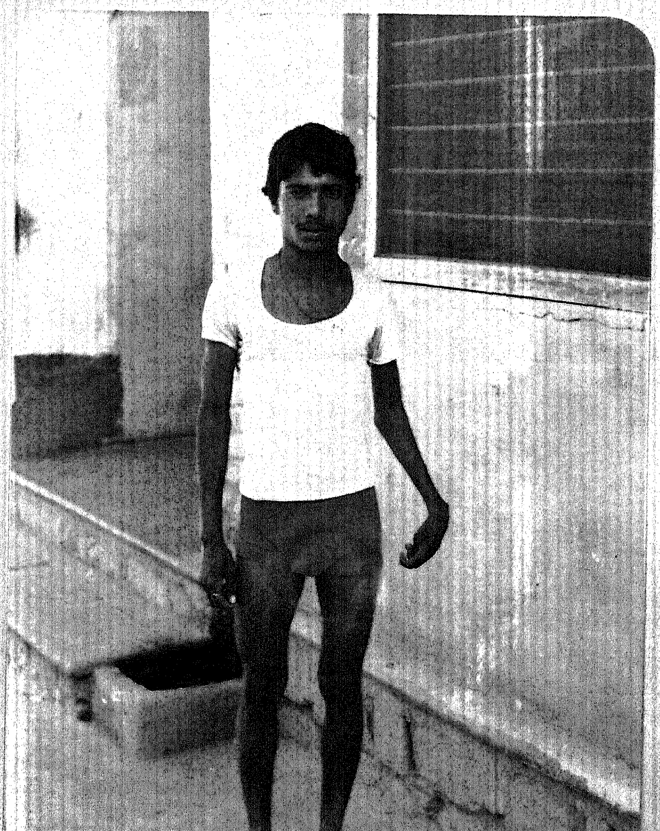


Another child with severe paralysis and flexion deformity at hip joints with hyper-extension of knee on one side (left) and flexion on the other (right). There is complete paralysis of quadriceps



Child aged nine years showing flexion defo-rmity at both hips and knees and equinus at both ankles and feet. There is extensive paralysis of abductors and extensors of hips, extensors of knees and extensors of ankles and toes. Unable to stand, she walks on all fours.

Male aged 21 years with generalized paresis of all the muscle of upper arm and forearm and hand.



DISCUSSION

DISCUSSION

In India, poliomyelitis commences in childhood and infancy. Eighty percent of the total cases occur in children below five years. The most vulnerable population in India is the one between six months and three years. In U.S.A. 25 percent of cases are over the age of 15 years. The shift to age incidence is attributed to better standards to environmental sanitation. Males are more prone to clinical attack in ratio of three males to one female (Park and Park, 1983).

Age of involvement	Park	Present study
i) Cases $<$ 3 Yrs. of age	80%	89.6%
ii) Cases $<$ 6 Yrs. of age	95%	97.6%

In present study out of 290 patients, 224 were males as compared to 66 females with the ratio of 3.4:1 (77.2 percent were males and 22.8 percent females). Age of involvement was calculated in different age groups and maximum age incidence was found in children below one year of age. All studies inferred male preponderance over females.

Infants born of immune mothers escape infection upto the age of six months. Thereafter they become susceptible to poliomyelitis, the susceptibility being maximum in the age group six months to three years. By the age of five years, over 90 percent of the children show the presence of antibody to one or more of the three types of polio

Age incidence of study group was maximum between 10 and 20 years. Youngest patient was of two years of age while eldest was of 70 years. Average age of study group was 13.2 years.

Involvement of lower limb was much more frequent as compared to upper limb. In present study 96.5 percent cases were of lower limb involvement. Of this 78.6 percent were of unilateral involvement while rest 21.4 percent were bilaterally affected.

Upper limbs were affected in 4.5 percent cases. As a whole 16 upper limbs were affected. Of these 15 were unilaterally involved while one case had bilateral affection. There was no trunk involvement in our study. I got one case of residual paralysis in which there was 7th cranial nerve involvement.

Involvement	Lovett's findings	Findings in present study
Both legs	127	60
One leg	85	220
Both legs and both arms (all extremities)	55	01
Arm and leg involvement (Upper limb with lower limb)	71	05
One arm	19	10
Both arms	04	01

Lvoett (1917) worked out tables - showing regional involvement of extremities in poliomyelitis. He found that

maximum number of cases were of bilateral lower limb involvement, unilateral involvement being less than half of this. But these findings were reversed in present study showing maximum involvement of lower limb unilaterally. While bilateral involvement was less than one third of unilateral involvement, the ratio being 1:3.6. Upper limb involvement was not that much frequent in our study.

In this study, most common involvement was of unilateral lower limb followed by bilateral lower limb involvement. There were only five cases in which one upper limb and one lower limb was involved, out of 290 cases.

When upper extremity was considered there was a distribution of much importance - out of 16 cases, 13 cases were of left sided involvement while two were of right side involvement and in the remaining case all the extremities were affected.

Legg (1929) noticed that lower limbs show a higher frequency of involvement than the arms, with practically no preference for right or left side. At present, there were 280 cases of lower limb affection while upper limb involved in 16 cases only.

Right lower limb was affected in 42.8 percent cases while left limb was affected in 37.7 percent cases. Thus there was no practical difference between right and left lower limb involvement.

According to Lovett (1915) partial paralysis (paresis) was much more common than total paralysis.

	Total No. of affected muscles	Partial paralysis (No. of muscles)	Total Paralysis (No. of muscles)	Ratio of paresis to paralysis
Lovett	1,452	1,036	416	2.5:1
Sharrard	2,464	1,502	962	1.56:1
Present study	4,435	3,313	1122	2.95:1

Above table clearly indicates that number of paretic muscles was always greater as compared to complete paralysis. Lovett studied 1,452 affected muscles and got a ratio 2.5:1 of paresis to paralysis. Which was 1.56:1 in study of Sharrard. In our study this ratio was 2.95:1. This ratio of partial to total paralysis varied in individual muscles. The ratio was maximum for intrinsic muscles of foot and minimum for quadriceps. This ratio also indicates susceptibility of particular muscle to paralysis, minimum the ratio, highest the susceptibility to paralysis, while maximum ratio denotes least susceptibility.

The greater susceptibility of some muscles to complete paralysis than others is explained in the following way. The motor cell columns of some muscles are short and of others are long. In the lumbar segments, the tibialis anterior and tibialis posterior possess short columns and are surrounded by the longer columns belonging to the

quadriceps. hamstring muscles and adductors. A small focus of poliomyelitic destruction affecting mainly the 4th lumbar segment severely damages the nuclei of the two tibialis muscles and causes them to be paralysed, while the other nuclei suffer a partial loss of their substance which, at the most, result in a mild paresis of the muscles they supply.

Thus muscles whose nuclei extend over only a short length of spinal cord are very susceptible to paralysis and muscles with long motor cell columns are more likely to remain clinically unaffected or suffer a paresis only.

"The muscles nearest the trunk are most frequently affected, distal group of muscles being least frequently affected" (Lovett, 1917). He also told that there was noticeable difference between left and right upper limbs but there was no difference between right and left lower limbs.

In our study there were 120 cases of right lower limb while 100 cases of left sided involvement. But there was marked difference between right and left upper limb involvement, left sided involvement was much commoner as compared to.right.

Hips were involved in 318 limbs while second was knee, affected in 316 limbs which was followed by ankle in 303 limbs. Distal group of muscles was involved in 186 limbs. Above data clearly indicate that frequency of

paralysis is maximum nearest the trunk and it decreases as one goes distally. Out of 340 affected limbs there were 154 limbs in which distal group of muscles in lower limb was spread. This sparing of distal muscles was a general tendency in affected polio patients (Lovett 1915).

These findings can be explained on the basis of active use of right and left limbs respectively. This hypothesis was given by Lovett (1915). He told that left upper limb is less frequently used as compared to right upper limb, so that blood supply is more free around the spinal centres where the motor activity is greatest and most complicated and are less likely to get attacked on their nerve centres by paralytic polio virus. That is why right upper limb is less frequently involved.

Above explanation also holds true to explain the frequent involvement of muscles near the trunk. These muscles have to work less frequently and perform uncomplicated movements while the distal muscles perform complicated and finer movements much frequently, therefore they have better blood supply around their spinal centres and are less likely to be affected. Conversly in case of lower limbs both legs have to do equal function and in consequence there is no difference in severity of paralysis in both lower limbs.

Another feature which was observed during present study was that there was much more diffuse involvement of

limbs as compared to localized patchy involvement reported by others. Hips with knee with ankle were involved in 270 limbs. While hip alone was involved in nine limbs, knee alone in three and ankle in three limbs.

These data indicate extensive involvement in post polio patients in India. While in other European countries, where the environmental sanitation is definitely better and health services are in very good condition, distribution is patchy in nature.

In India, poliomyelitis is much prevalent and health services are inadequate. That is why polio is in its severest form here and muscle recovery is also very less. This is the reason why here we find diffuse involvement.

In present study, incidence of affection was maximum in hip flexors, quadriceps and hip abductors. Distal group of muscles was affected least frequently. Hip flexors were affected 318 times while flexor hallucis longus was affected only 165 times, i.e. hip flexors were approximately two times more (1.93 times) affected as compared to flexor hallucis longus. These findings coincide with the findings of Lovett and Sharrard and can be explained by the theory of Lovett (1917) that muscles near the trunk are much more involved as compared to distal ones.

But as regards incidence of paralysis, knee extensors (quadriceps) and tibialis anterior followed by hip adductors are much frequently paralysed while the distal group

of muscles were again at the bottom of the table. Intrinsic muscles of foot were least frequently paralysed (only in 8 limbs as compared to quadriceps which was affected in 142 limbs i.e. 17.75 times more).

These findings differ at some points with the findings of Sharrard. He noted that the largest number of paralyses were found in the distal group of muscles. He explained this stating "the severity of paralysis is proportionate to the weight to be met by the muscles at different levels. It may retard the recovery of those muscles which are working against greatest weight". But he failed to explain his own findings of very low incidence of paralysis in the intrinsic muscles of foot which by previous explanation should be the most frequently paralysed.

Skinhoj (1949) contradicted above explanation saying - "there is no quality of the muscles such as size, function, position in the limb or phylogenetic development that can satisfactorily explain the frequent affection of some muscles and the high proportion of paralysis in others.

But we can explain the findings of present study by the previous reasoning that muscles near the trunk are much frequently affected. That is why distal muscles are least frequently affected as well as paralysed. But we can not explain the frequent paralysis of quadriceps and tibialis anterior as compared to hip flexors and extensors.

Some muscles are supplied by Shorter columns of cells than others. But the root supply as a guide to the length of a muscle column may be deceptive. The tibialis anterior is supplied from the 4th and 5th lumbar segments but the supply from the 5th segment is small and the motor cell column is very short. The upper lumbar segments are more than twice as long as their numerical counterparts in the sacral segments, so a muscle supplied by all of the first and second lumbar segments has a column twice as long as a muscle supplied by the first and second sacral segments.

According to Sharrard (1955) the segmental distribution of muscles affected and muscles paralysed show that the second and third lumbar spinal segments were most frequently affected while fourth lumbar segment was most commonly involved in complete paralysis.

During our study, when segmental incidence of affection was seen, the first lumbar spinal segment was most frequently affected followed by second and third lumbar segments. The fifth lumbar segment was least frequently affected. But in case of segmental incidence of paralysis, the second and third lumbar spinal segments were most frequently paralysed followed by the first lumbar. The second sacral spinal segment was least frequently paralysed.

In present study, we got approximately same results as of Sharrard (1955). The quadriceps, tibialis anterior and hip adductors were most susceptible followed by hip

extensors and tibialis posterior. Distal group of muscles, having least susceptibility.

Sharrard (1975) regarded poliomyelitic paralysis as a haphazard affection of muscles, most frequent in the leg. In the cord lesion it appears to have a purely accidental distribution most marked in the lumbar enlargement. It is possible, however, that there are other factors than the cord lesion which determine the ultimate condition of the affected muscles.

When association among different muscles or muscle groups was seen, it gave clear interpretation that involvement was extensive or diffuse in nature, in place of patchy. It gives a false impression about the nature of poliomyelitic involvement, not being of patchy distribution. But the involvement, in this particular geographical distribution of Bundelkhand region was extensive. At first sanitary conditions are not adequate and even worse in rural areas. Which is superimposed by inadequate health services, they get. In rural areas the affected child is treated by quacks without making diagnosis. Again massage and injectibles are given to the patient without knowing its consequences, contrary to rest and no injection pricks, which aggravates the paralysis and hamper muscle recovery. As an outcome more number of muscles of affected limb are involved and with no or least recovery producing a picture of such extensive involvement.

Associated paralysis may be explained as follows - 'In nuclear representation in the spinal cord, the columns for associated muscles lie side by side and extend over approximately the same length of cord. If one of the nuclei is completely destroyed by poliomyelitic affection, it is very likely that the other will be destroyed also. Hence, these muscles are associated in paralysis and coversly in freedom from paralysis (Sharrard 1955).

The pattern of paralysis can be correlated with the existance of appropriate focci of destruction in the motor cell columns of the spinal cord. If for instance, all the motor cells in lumbosacral cord are destroyed, except for those in the 3rd sacral segment, the common flail limb, in which only the intrinsic muscles of the foot are active, will result. A focus of destruction limited to the central part of the second, third and fourth lumbar segments produce paralysis of quadriceps and tibialis anterior.

CONCLUSION

CONCLUSIONS

A study of two hundred and ninty patients having post-polio residual paralysis was carried out. Patients were examined clinically for involvement of different muscles and muscle charting was done accordingly. After interpretation of collected data, following conclusions were drawn :

1. Age of involvement is maximum in 'below one year' of age group and incidence decreased sharply above ten years.
2. Males always predominated more than three times, in frequency of involvement when compared with females.
3. Upper limb involvement was negligible (5.4 percent) in comparision to lower limb (94.6 percent).
4. Unilateral involvement was much more common than bilateral involvement. Left upper limb was most commonly involved while both lower limbs were affected equally.
5. The involvement was on the whole more frequent at the hip and diminished in frequency towards the foot; that is the individual muscles in the upper segment were more often affected than in the lower.
6. Incidence of affection was maximum in hip flexors followed by quadriceps, hip abductors and tibialis - anterior and least in distal group of muscles.

7. Incidence of paralysis was maximum in quadriceps followed by tibialis anterior, hip adductors and hip flexors. Distal group of muscles was again least paralysed.

8. The quadriceps, tibialis anterior and hip abductors showed maximum susceptibility to paralysis. Intrinsic muscles of foot were the least susceptible.

9. Extensive diffuse involvement was much more common as compared to patchy involvement.

10. Segmental incidence of affection was maximum in first lumbar spinal segment followed by second and third lumbar spinal segments. Second sacral segment was least involved.

11. Segmental incidence of paralysis was maximum in second and third lumbar spinal segments and least in second sacral segment.

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SERIAL NO. . . . . . .   DATEF. . . . . .

NAME . . . .   AGE/SEX . . . .

ADDRESS . . . .

PARALYSIS : UPPER LIMB - Rt.   LOWER LIMB - Rt.   TRUNK

- Lt.   - Lt.   RESPIRATION

DURATION OF DISEASE : . . . .

MOBILITY : WALK BEFORE PARALYSIS ? ..... WALK NOW ? ...ONLY CRAWL? ..

ANNEXURE - I

POWER RIGHT

SHOULDER | ELBOW (ARM) | FORE ARM | WRIST | FINGERS & THUMB

CERVICAL SEGMENT 5 6 7 8 | DORSAL 1

DELTOID
LATISSIMUS-DORSI
TERES-MAJOR
SUPRA S.
PECTORALIS - MAJOR
TER. MIN.
INFRASPINATUS
SUBSCAPULARIS
BICEPS
BRACHIALIS
BR. RADIALIS
TRI CEPS
SUPINATOR
PRONATOR TERES
PRONATOR QUADRATUS
FLEXOR CAR. RAD.
FLEX. CARD. ULNARIS
PALMARIS LONGUS
EXT. CARPI. RAD. - L. B
EXT. CARPI. ULN.
FLEX. POLL. LONG.
EXT. POL. LON.
ABD. POL. BREV
EXT. POL. LONGUS
EXT. DIGITORUM
EXT. INDICIS
EXT. DIGIT MIN.
FLEX. DIGIT. SUBLIMIS
FLEX. DIGIT. PROFUNDUS
FLEX. POLL. BREV.
OPPONENS POLL
OPP. DI. MIN.
ADD. POLLICIS
ABD. DIG. MINIMI
LUMBRICALS
INTEROSSEI

POWER LEFT

POWER RIGHT

HIP | THIGH | LEG | FOOT

DORSAL 12 | LUMBAR SEGMENT 1 2 3 4 5 | SACRAL 1 2

ILIO-PSOAS
T.F.F.
GL. MAXIMUS
GL. MEDIUS
GL. MIN. Med. Rot.
OBT. EXT.
QUAD. FEMORIS
OBT. INTERNUS
SARTORIUS
ADD. LONG.
GRACILIS
ADD. BREV
ADD. MAG.
INNER HAMSTRINGS
BICEPS FEMORIS
QUADRICEPS
TRICEPS SURAE
TIB. ANT.
TIB. POST.
PER. LONG
PER. BREV.
EXT. HALLON
EXT. DIG. LONG
FLEX. DIG. LONG.
FLEX. HAL. LONG.
EXT. HAL. BREV.
EXT. DIG. BREV.
LUMBRICALS
INTEROSSEI

POWER LEFT